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SRS Computer Animation and
Drive Train System

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ABSTRACT

The spinning rocket simulator (SRS) is an ongoing project at Oral Roberts University. The goal of the SRS is to gather crucial data concerning a spinning rocket under thrust for the purpose of analysis and correction of the coning motion experienced by this type of spacecraft maneuver. The computer animation simulates a virtual, scale model of the component of the SRS that represents the spacecraft itself. This component is known as the (VSM), or virtual spacecraft model. During actual physical simulation, this component of the SRS will experience a coning. The goal of the animation is to cone the VSM within that range to accurately represent the motion of the actual simulator.

The drive system of the SRS is the apparatus that turns the actual simulator. It consists of a drive motor, motor mount and chain to power the simulator into motion. The motor mount is adjustable and rigid for high torque application. A digital stepper motor controller actuates the main drive motor for linear acceleration. The chain transfers power from the motor to the simulator via sprockets on both ends.

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Volume I

Introduction

Since the Spinning Rocket Simulator (SRS) is an ongoing project at Oral Roberts University work continues until a working model is achieved for testing. However, this is the last year that Dr. Dominic Halsmer will receive funding for the project. If more funding is needed for the project in the future a progress report may be needed for presentation to N.A.S.A, for continuation of the grant money. Therefor, a computer animation of the SRS may be very helpful in the presentation of the current apparatus. The animation presents a whole new field of study for the observation of space dynamics in a virtual environment.

The project of animating the system is now under way and now provides a platform for further studies of the SRS. So, in order to build the necessary platform a model of the system is constructed in a CAD program or equivalent. Then programming is used to control the model and vary its actions. The optimal system is one in which the animation may have variable parameters, which can be controlled by the program, and then reflected on the model.

The second part of this project - the drive system - takes on the same goal as the first and is needed for a complete SRS project. The drive system is needed for physical control of the spin speed of the linear track described within. This system guarantees a smooth operational system by using a linearly controlled electric motor. The design of this system involves previously chosen components to achieve the desire operation of this system. A motor mount incorporated with the existing parts will complete the drive system.

Project Development

Animation

In the development of this project, some major aspects had to be considered to ensure the quality and completeness of the project. It was decided from the start to divide the project into two distinct phases, one consisting of the animation aspect and the other consisting of the drive train aspect. Hence, development of theory for the animation is considered first.

The basic concept that is considered during the first phase of the project is to develop a platform for the animation of a virtual, three-dimensional model. (See appendix 1) Primary to the completion of the project is this platform, from which the virtual model can be manipulated to correctly animate the true motion of the actual model. Secondary to but not necessary for completion, this platform is to provide an interface from which the virtual model can be driven through real-time, streaming, and serial or parallel data. Considering this, an appropriate software platform to create the model and platform has to be chosen. After a review of various CAD (Computer Aided Design) and animation packages and given the time frame with which to work, Solid Works clearly emerged as the most appropriate package. Henceforth, design theory is clearer and an approach is developed to build and animate the three-dimensional model. In design of the platform from which the model could be animated, some sort of interface is needed. The Solid Works API (Advanced Programming Interface) is the method for implementation. This interface provides two of the key concepts necessary to the design theory: a means by which to drive the animation and a platform for further

forms of data being interfaced with the model. Considering the means by which the animation is driven through the API, a script must be completed that is “read” by the API and translated into actual movements of the virtual, three-dimensional model on-screen. The idea of a “script” that is interpreted by the API is the main conceptual landmark in phase one of the project. (An exhaustive breakdown of a script used for sample animation can be found in appendix 2.2) This script is written in Microsoft Visual Basic, an object-oriented programming language that provides the necessary compatibility for interfacing with other types of data, as it is primarily a function driven language. An assumption is made at this point that indeed a successful interface can be made with the virtual, three-dimensional model by means of the API and use of Microsoft VB. This consists of programming a type of port to “listen” for incoming data and send it to the API. Once these main theoretical concepts are developed for phase one, consideration of phase two theory and design begins.

Drive System

The drive system (appendix 3), being a subsystem of the physical SRS has design approaches different than that of the animation project. The only shared theory and design work involves the extensive use of a three-dimensional CAD program for visual design and testing. The rest of the concepts considered for the drive system center around the need to turn the linear track at one revolution per second. In order to do this, the previously existing parts of the drive system are recognized and evaluated as needed, or not needed. Once recognized, the parts are implemented into the theory behind the design. A Complete drive system has been previously designed for the

system. However, after some evaluation it is determined that a more efficient design would be necessary. The design of the new drive system centers on the necessity of the drive chain to run under tension for smooth operation. Therefore, a robust motor mount (appendix 3.1, 3.8) is needed for the chain to be held in tension. When looking at a chain drive system using sprockets for power transfer, the need for an adjustable system is required for assembly and tension management. In order to create a flexible drive system, most of the adjustments are taken up in the motor mounting apparatus. The tension on the chain also creates significant forces on the motor, which are absorbed by the motor mount. When looking at the drive system proper manufacturing techniques and operations are also needed to achieve a robust motor mount based on design criteria.

Project Validation Procedures

Animation

Given that the animation in phase one is purely software driven and not a hardware issue, only one prototype is constructed in Solid Works to facilitate an initial understanding of potential animation techniques. The successful animation of a prototype also ensures that animation of the actual model will be attainable in the same fashion, and hence meet the specification that it is to represent its dynamics (coning motion) in relation to the other sub-systems of the SRS. Secondly, in order to ensure an accurate model of the actual spinning rocket subsystem of the SRS, measurements using micrometers and calipers are taken and transferred to the dimensions of the virtual model. More important to the construction of the virtual model were the properties of the components on-board the subsystem rather than the mere aesthetics. In order to

ensure subsystem assembly accuracy, each part is created separately with its own measurements. This way if the assembly does not assemble together exactly true, errors are traced and fixed easily. The assembly of the subsystem occurs in an assembly program, in which the individual parts are brought into the same environment and mated using their own individual properties to relate to one another.

Testing of the animated assembly, once constructed, consists mainly of varying parameters in the animation script to observe the functionality of the animation technique. Parameters such as cone angle and spin rate can be varied to adequately accommodate the range of motion and degrees of freedom of the actual model. Phase two takes on a more traditional approach, as it is primarily hardware oriented.

Drive System

A Solid Works prototype of a motor mount for the drive system depends on acquiring a range of tensions for the chain drive system. Therefore through calculation and rough experimental values, a range of forces is found. Using the tension calculations a motor mount is designed to distribute the forces encountered by the system. Bolts that attach the motor to the motor mount transfer most of the force from tension to the floor. (Appendix 3.1) The bolt size and strength is determined by the force distribution between electric motor and motor mount. (Appendix 3.8) However, the motor has strength restrictions due to manufacturer constraints on the mounting hole diameters. (Appendix 3.6) Due to this constraint an initial prototype of the motor mount was designed around these considerations. The design of the first motor mount prototype was designed around the different forces acting the system, in order to distribute them. The forces acting on the system are torsion, axial and shear forces.

Secondly, a more economic approach can be taken for cost and manufacturing reasons. (Appendix 4) Thus, steel is a good choice as the motor mount material for its strength and cost properties. However, in evaluating the first prototype mount, excess material was not needed which results in a more concise design. Therefore, the final prototype shows a simple, inexpensive, adjustable, but rigid system that distributes forces well. (Appendix 3.5) The adjustments for the system are seen in the four bolts that protrude from the motor to the motor mount. These bolts with nuts provide the necessary mechanical advantage to tighten the chain on the motor. (Appendix 3.6) Along with the bolts there is a six-inch range in slide for adjustments, and once adjusted four bolts tighten the motor down to the base of the motor mount. (See appendix 3.1 and 3.2) Aside from the distribution of forces the motor mount's base is designed so that it can be mounted into the ground of the Space Dynamics lab. In doing this, a joist and beam structure –common in buildings- is used to minimize plate deflection and torsion on the base when the mount is secured to the floor. (See appendix 3.5). Finally the bolts used for mounting the drive system into the floor are chosen to minimize deflection of the motor mount.

Testing and Results

Animation

Phase one of the project is successfully completed as evidenced by a concise comparison of the initial design plan and the finished product. Initially, an animation of a three-dimensional model which when completed will accurately represent the dynamics of the sub-assembly in relation to the other sub-systems of the SRS is determined. This,

coupled with the necessity for a platform that could be used to integrate real-time data into the animation program, will result in over and above completion of the project. As phase one stands, a working, highly presentable three-dimensional animation of the Virtual Spacecraft Model is present and functional. The Visual Basic animation script provides the necessary functionality to the model's degrees of freedom to represent the coning motion of the model reasonably well. Secondly, the script provides one means of interfacing with real-time data flow as perhaps a continuous part of this project. In summary, it can be stated after a careful comparison of the initial goals with the project results that phase one is completed successfully with minimal deflection from the original design layout. As concrete evidence, the animation itself can be viewed on the web page dedicated to the SRS. (See appendix 6)

Drive System

The drive system of the SRS is not ready for operation as of yet but it is fully capable of performing as designed. The drive motor of the system can be turned on and tested using the linear controller mounted on the wall of the Space Dynamics lab. The motor can be mounted in the motor mount, which is assembled and ready to be mounted to the floor of the room. When the motor is in the mount it can be tested for rigidity and firm mounting by applying test forces to the system. When test forces are applied minimal deflection of the mount is observed. The motor can also be adjusted using the mechanical advantage of the tightening apparatus built into the motor mount. The motor has about a six-inch range of motion so that the chain of the drive systems can be brought into proper tension. The only part of the mount that is not complete is

the legs of the motor mount, which need to be mounted into the floor of the SRS room. This should be done within the next few weeks.

Conclusions and Recommendations

Animation

Given the time restraints and experience prior to phase one of this project, the choice to use Solid Works as the model building and animating software is beneficial. The coning motion experienced by the actual model is represented well by the Visual Basic script-driven virtual model run through the API. Also, the animation is presented in a highly aesthetic format on the web page, as mentioned earlier.

Drive System

The drive system of the SRS is complete and has the capability to drive the linear track, but is not yet installed. The requirements of the motor mount are described in the definition of completeness and are met in all aspects therein. The motor is adjustable and secure in the mount, and has the ability to rotate the linear track using two sprockets, and a chain. However, it is my belief that a direct drive system would have been a better choice for this type of project. A direct drive system provides a more stable system than that of a chain drive. A chain drive system will always flex and deflection in the system is a given. Thus, backlash and other adverse affects can be encountered. But, the design depended on existing systems and previous work done in the past, which limited design parameters. The project cost was no more than specified, and is within a couple dollars of the estimated cost. Drive system cost where lowered

considerably by incorporating steel instead of aluminum which was in consideration from previous designs.

References

- Bennett, Damon. Motor Mount Drafts, Schematics, and Design. Oral Roberts University Engineering, Fall 1998/Spring 1999.
- Halsmer, Dominic. The Dynamics and Modeling Fidelity of an Apparatus to Test the Stability of Spinning Spacecraft Under Thrust. AAS/AIAA Space Flight Mechanics Meeting, Huntsville, Alabama, February 10-12, 1997.
- Hamrock, Bo, and Steven R. Schmid. Fundamentals of Machine Elements. Boston: McGraw-Hill, 1999.
- Hibbeler, R.C. Mechanics of Materials. Third Edition. New Jersey: Prentice Hall, 1997.
- Lincoln Electric. The Procedure Handbook of Arc Welding. Twelfth Edition. Ohio: Lincoln Electric Co: 1973.
- Slaton, Clay. Personal Consulting Interview. 23 Oct. 2000
- Solid Works. CAD Computer Software. Solid Works, 2000. PC-Windows 2000, Pentium II, CD-ROM.

Volume II

Planning Phase

For phase one, the cost estimation was fairly easy. Since phase one is software driven, requiring Solid Works and a computer only. Also, the Visual Basic language was supported by the Solid Works package. Hence, the budget for phase one was exactly nothing. This estimation proved correct, and is one of the advantages of developing a software-oriented project. Estimation for the drive system is fairly predictable because all labor would not be contracted out to a machine shop. Therefore, the material costs were the budget, and hence it was more predictable. The budget can be seen in the Project Control Phase section.

Scheduling estimates were a little bit more difficult. Since the experience needed with Solid Works to create the virtual model was great, it was hard to figure in a correct time to devote to research. Clay Slaton, a local Solid Works expert and marketer, helped to figure how to schedule the processes needed to successfully complete phase one of the animation project.

It was determined for the group to focus more time in the beginning to the animation of the three-dimensional model, as it proved to be the area that would require more research, and a buffer of time would be good. Along with the animation research a significant amount of time would be spent on the drive system details. Focuses then shift onto phase two towards the end of December. Planning for phase two was not as difficult for the animation, as it was more of a physical project that utilized more documented and common procedures for completion. The drive system however has to be designed to meet specifications needed for completion.

The decision to give more time in the beginning to the animation in phase one proved to pay off. If time had been given to this later on, and phase two was given priority instead, the project might not have been completed on time. The time spent on developing the computer model ultimately aided the design of the motor mount. This is true because the computer model of the motor mount provided an easy way to alter and strengthen the design of the system.

Project Control Phase

The management aspect of the project goes as follows: group focus started on research concerning Solid Works techniques for construction and animation of the virtual model of the SRS as well a preliminary design of the drive system. Once the research was completed to the point where work could begin, complete attention was diverted to constructing the virtual model. Once complete, attention was shifted to the drive train design work and animation of the virtual model. No significant deviations from the original plan occurred. The timeline and budget are given below in more detail:

Timeline

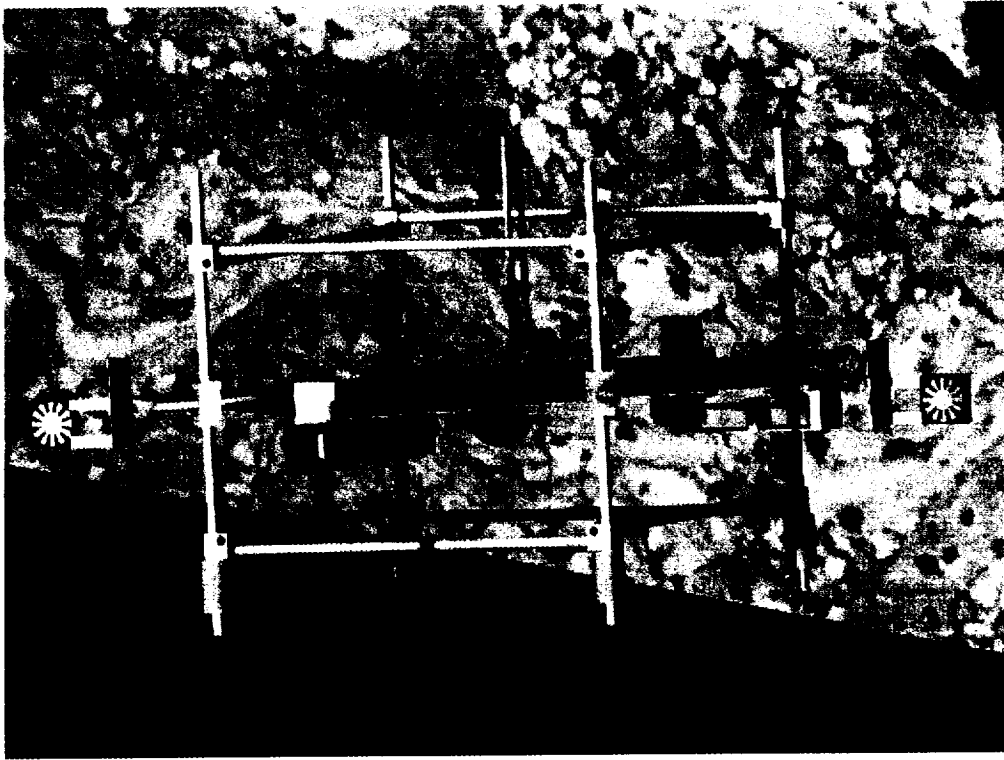


Budget

The project's only expenditure was \$50 dollars for material to construct the motor mount for the drive train system. This was completely on target from the original expenditure expectations.

Appendix

1 Virtual Model



2 Visual Basic Script

```
'*****  
' C:\WINDOWS\TEMP\swx-132925787\Macro1.swb - macro recorded  
on 11/27/00 by sch11607  
'  
*****
```

```
Dim swApp As Object  
Dim Part As Object  
Dim boolstatus As Boolean  
Dim longstatus As Long  
Dim Annotation As Object  
Dim Gtol As Object  
Dim DatumTag As Object  
Dim FeatureData As Object  
Dim Feature As Object  
Dim Component As Object
```

```
Sub main()
```

```
Set swApp = CreateObject ("SldWorks.Application")  
Set Part = swApp.ActiveDoc
```

```
Part.ViewRotateplusx  
Part.ViewRotateplusx  
Part.ViewRotateplusx  
Part.ViewRotateplusx  
Part.ViewRotateplusx  
Part.ViewRotateplusx
```

```
For I = 1 To 25
```

```
Part.ActiveView().ZoomByFactor 1.02
```

```
Next I
```

```
For I = 1 To 12
```

```
Part.ActiveView().RotateAboutPoint -.005, 0, -0.100175, -  
0.147001, 2.55228e-005
```

```
Next I
```

```

For I = 1 To 100
Part.ActiveView().RotateAboutPoint 0, 0.1, -0.136999,
0.108298, 2.55228e-005

Next I

For I = 1 To 20
Part.ActiveView().ZoomByFactor 1.08

Next I

For I = 1 To 100
Part.ActiveView().RotateAboutPoint 0, 0.1, -0.136999,
0.108298, 2.55228e-005

Next I

For I = 1 To 20
Part.ActiveView().ZoomByFactor 0.92

Next I

For I = 1 To 215
Part.ActiveView().RotateAboutPoint 0, 0.1, -0.136999,
0.108298, 2.55228e-005

Next I

End Sub

```

2.1 Exhaustive Visual Basic Script

```

*****
// Within these declarations are defined the necessary
// variables and features to interface the script
// successfully with the Solid Works application window.
*****

Dim swApp As Object
Dim Part As Object

```

```
Dim boolstatus As Boolean
Dim longstatus As Long
Dim Annotation As Object
Dim Gtol As Object
Dim DatumTag As Object
Dim FeatureData As Object
Dim Feature As Object
Dim Component As Object
```

```
*****
// Start of main function
*****
```

```
Sub main()
```

```
Set swApp = CreateObject ("SldWorks.Application")
Set Part = swApp.ActiveDoc
```

```
*****
// Cone angle is varied with these statements with a
// correspondence of 1.5° per execution of each statement
*****
```

```
Part.ViewRotateplusx
Part.ViewRotateplusx
Part.ViewRotateplusx
Part.ViewRotateplusx
Part.ViewRotateplusx
Part.ViewRotateplusx
```

```
*****
// Zooming in on the model at a ratio of 2% per frame out
// of 25 frames of animation
*****
```

```
For I = 1 To 25
```

```
Part.ActiveView().ZoomByFactor 1.02
```

```
Next I
```

```
*****
// Cone angle is varied with the statement contained within
// a for loop correspondence of approx. 1.5° per execution
// of each statement. The first argument to the
// Part.ActiveView().RotateAboutPoint function is the
```

```
// control parameter, and the others coordinates center the
// mass around the center of mass of the air bearing
*****
```

```
For I = 1 To 12
```

```
Part.ActiveView().RotateAboutPoint -.005, 0, -0.100175, -
0.147001, 2.55228e-005
```

```
*****
// Within this for loop, the spin command is given. Also,
// the rate of spin is determined by the second argument to
// the Part.ActiveView().RotateAboutPoint function, and is
// increased or decreased accordingly.
*****
```

```
Next I
```

```
For I = 1 To 100
Part.ActiveView().RotateAboutPoint 0, 0.1, -0.136999,
0.108298, 2.55228e-005
```

```
*****
// Zoom by a factor of 8% per frame of animation for 20
// frames
*****
```

```
Next I
```

```
For I = 1 To 20
Part.ActiveView().ZoomByFactor 1.08
```

```
Next I
```

```
For I = 1 To 100
Part.ActiveView().RotateAboutPoint 0, 0.1, -0.136999,
0.108298, 2.55228e-005
```

```
Next I
```

```
*****
// Zoom by a factor of -8% for 20 frames of animation
*****
```

```
For I = 1 To 20
Part.ActiveView().ZoomByFactor 0.92
```

Next I

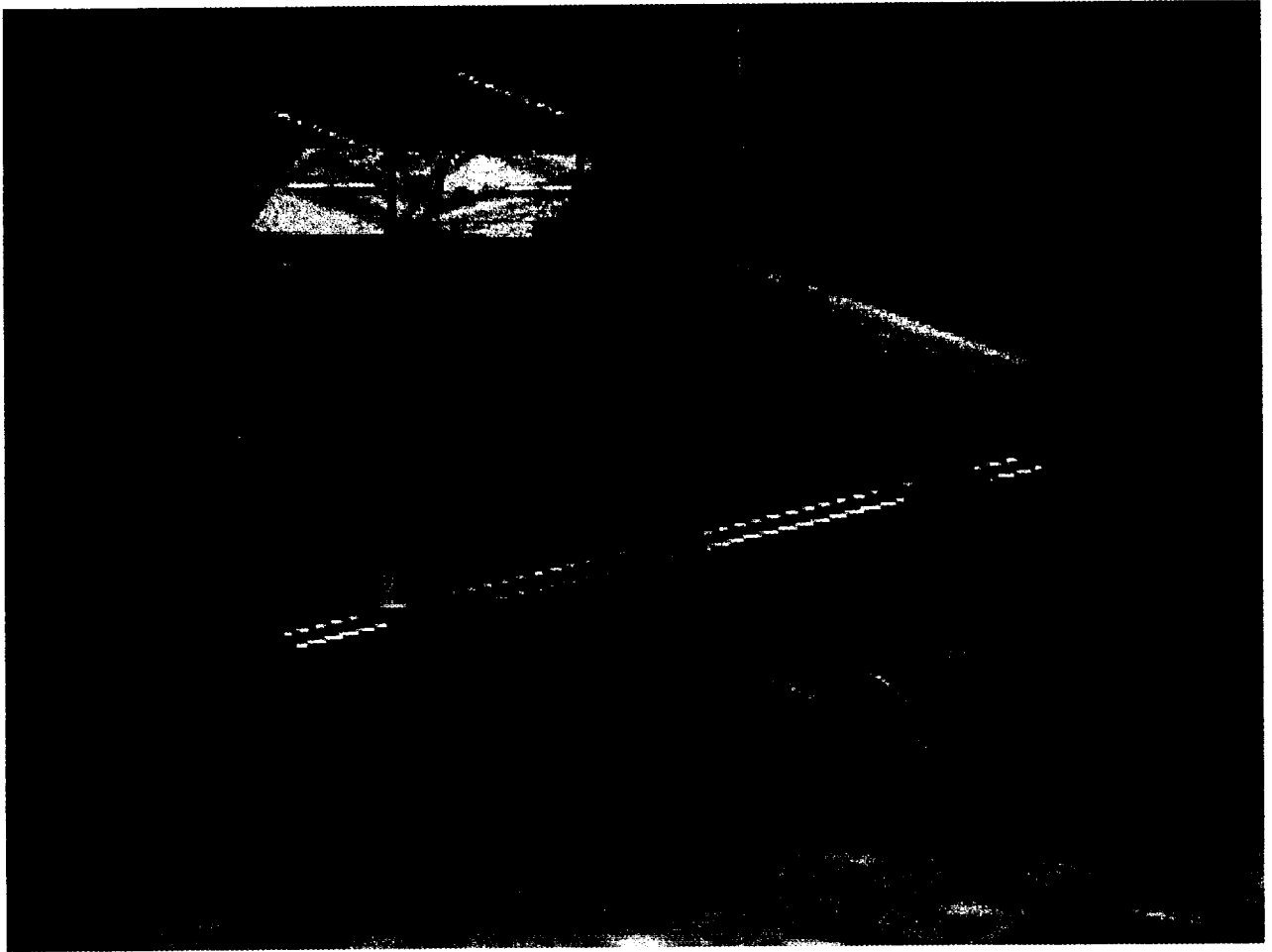
```
*****  
// Within this for loop, the spin command is given. Also,  
// the rate of spin is determined by the second argument to  
// the Part.ActiveView().RotateAboutPoint function, and is  
// increased or decreased accordingly.  
*****
```

```
For I = 1 To 215  
Part.ActiveView().RotateAboutPoint 0, 0.1, -0.136999,  
0.108298, 2.55228e-005
```

Next I

End Sub

3 Drive System

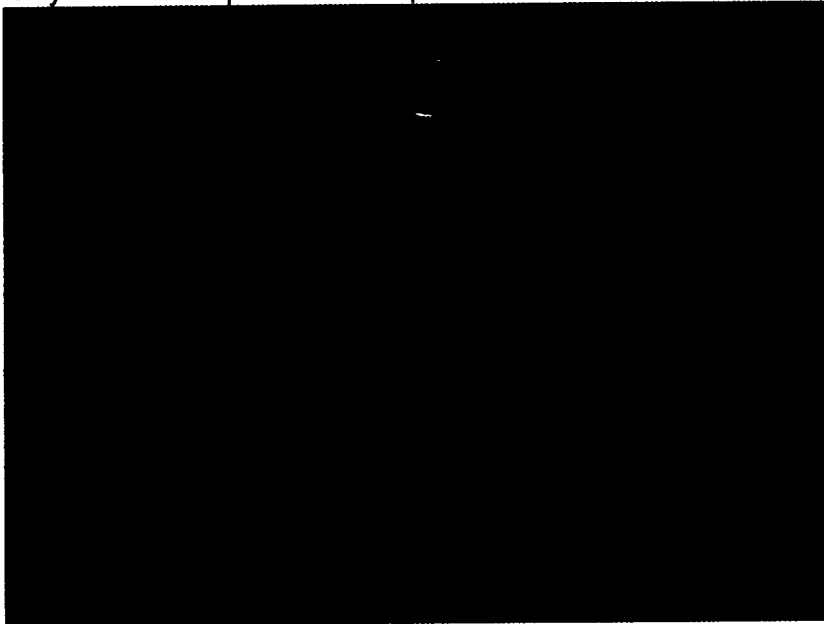


The Drive System is shown below as a subsystem of the whole Spinning Rocket Simulator as shown above. The main parts of the drive system can be seen below and are labeled accordingly.

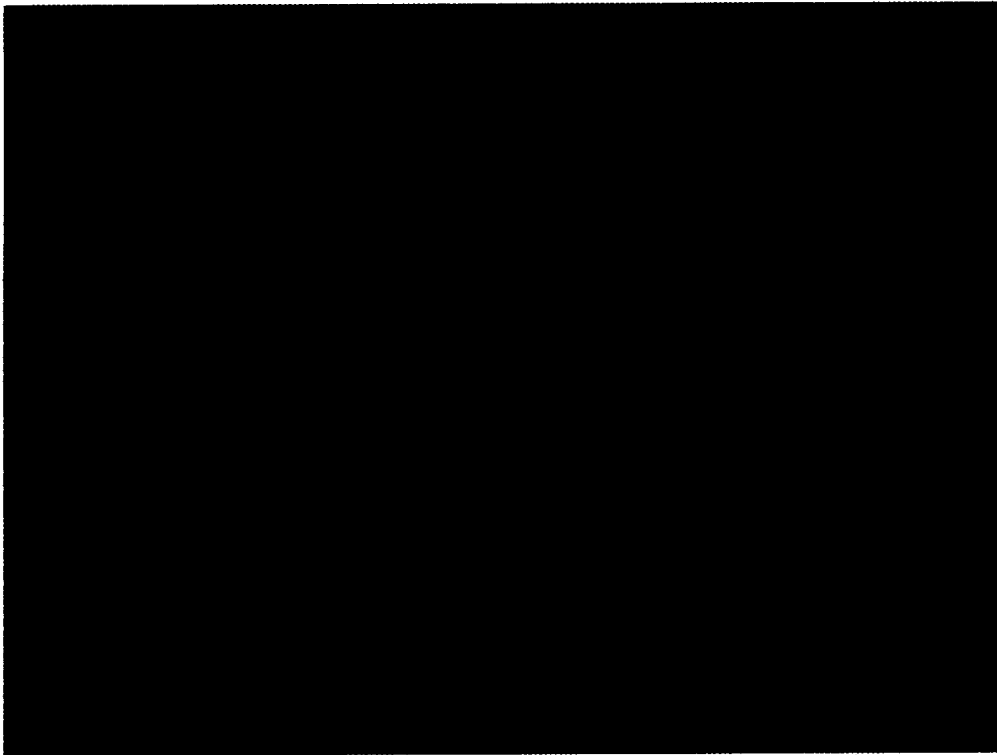


3.1 Motor Mount

The views below represent all the acting parts of the main design concentration- the motor mount- and the details of the design. The dimensions of all parts were determined by mechanical analysis of new parts and the integration of existing parts at the school. The main reason for the size and dimensions of the motor mount highly depended on the electric motor and its mounting brackets as set by the manufacturer (Note, dimensions are not given in any detail except for crucial parts and thickness in the following Appendices)



3.2 Motor Mount-Continued



Motor Mount Upper-

Designed around motor dimensions

Motor Mount Base-

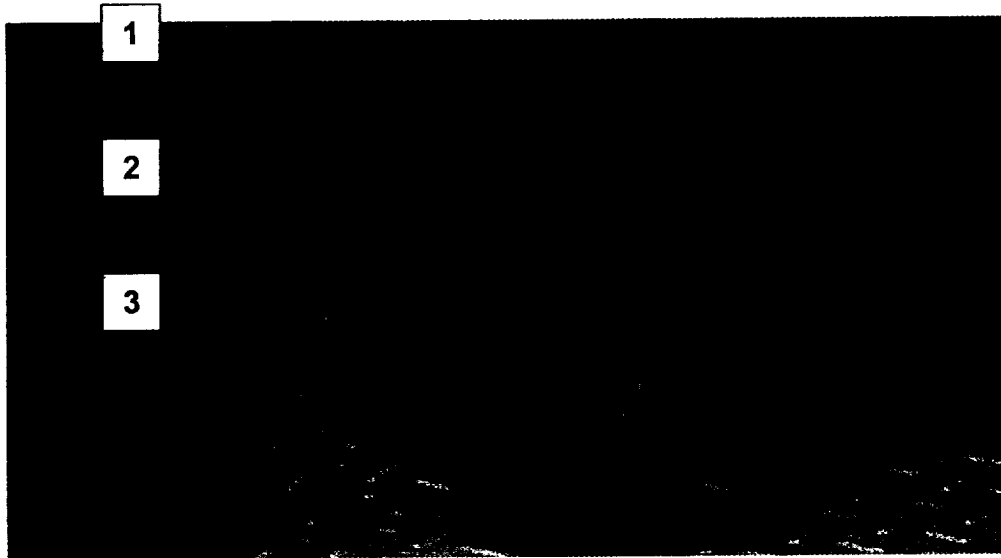
Designed to prevent twisting and Deflection of upper system

Motor Guide Plate-

Designed to tighten chain

3.3 Motor Mount Upper design

Upper system constructed of 5/16 inch plate steel that was welded together using 6013 strength rod.



1. Slide and mounting holes

- The three slides were incorporated to give a range of 6 inches for the tightening of the chain by pulling the motor with the nuts on the slide plate
 - The two longer slides accommodate bolts that hold the motor in place after moved into position.
 - The shorter slide provides a way for the motor's drive shaft

2. Vertical motor support

- The vertical motor support has four holes through it so that the Motor Guide plate is secured in position. The support also has fins along either end to counteract deflection.

3. Side motor support

- The Side supports on the motor mount were designed to prevent the torsion from the motor to act on the guide plate, and it also distributes any torsion into the base plate of the motor mount.

3.4 Static Displacement of Motor Mount Upper

The static displacement analysis was done using Cosmos works because of the complexity of the system. For the analysis forces were applied at the four holes in the back of the mount and four forces were applied where the motor would be secured to the base. The force applied at each hole was the maximum for design for, at 800 lbs. per hole.

- The static displacement of the motor mount excludes the base structure (See Appendix 3.2) used to strengthen the base plate
- Under maximum design loads for the fastening devices (800 lbs force per hole) system deflection is shown.
- Maximum deflection is 3.067×10^{-4} m or 0.010 in.
- Note, the deflection is minimized more with the base structure

Motor Mount Updated#2-Motor Mount Static Study :: Static Displacement
Units : m

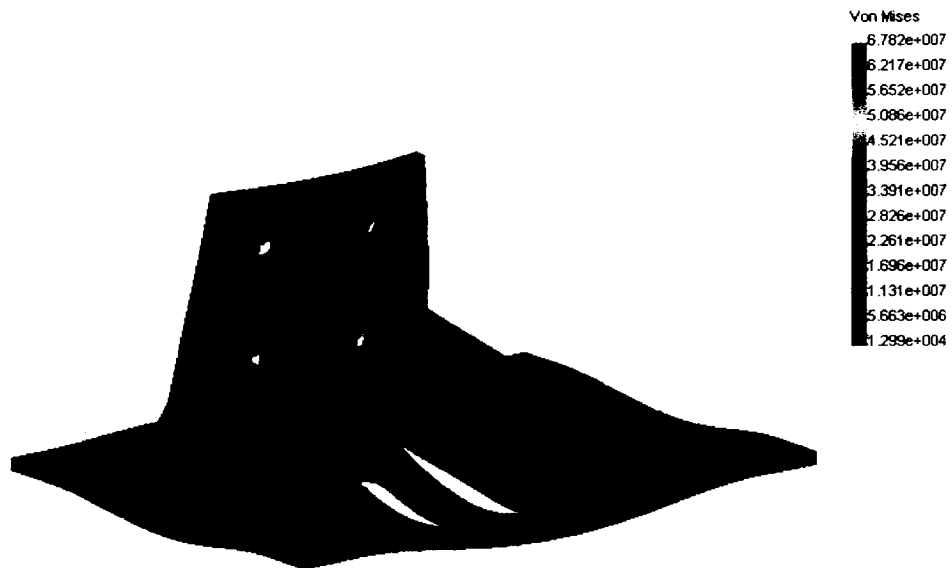


3.5 Motor Mount Stress analysis

The stress analysis was performed to determine the stress concentrations as well as the safety of the system.

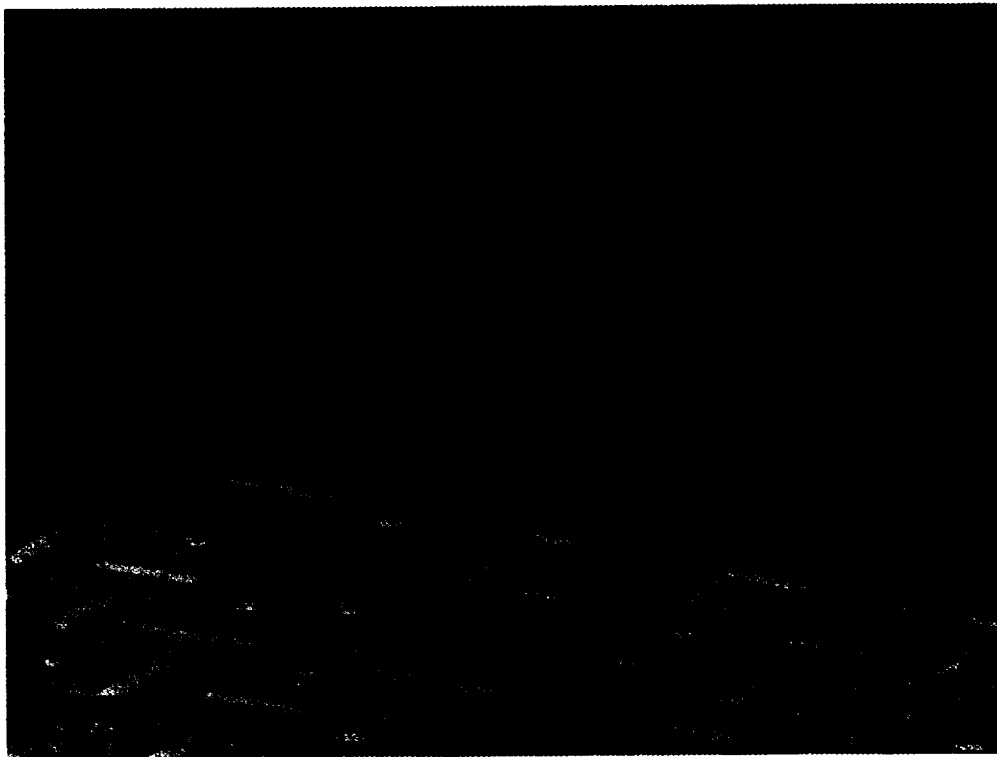
- The motor mount shown is a optimal design which is welded together to minimize cost but improve strength and rigidity
- The load conditions are the same as the displacement analysis
- The maximum stress for the conditions is around 30 Mpa which is much lower than the allowable stress for steel
- Note that the stress distribution is well distributed

Motor Mount Updated#2-Motor Mount Static Study :: Process-Bends Nodal Stress
Units : N/m^2



3.6 Motor Mount Base design

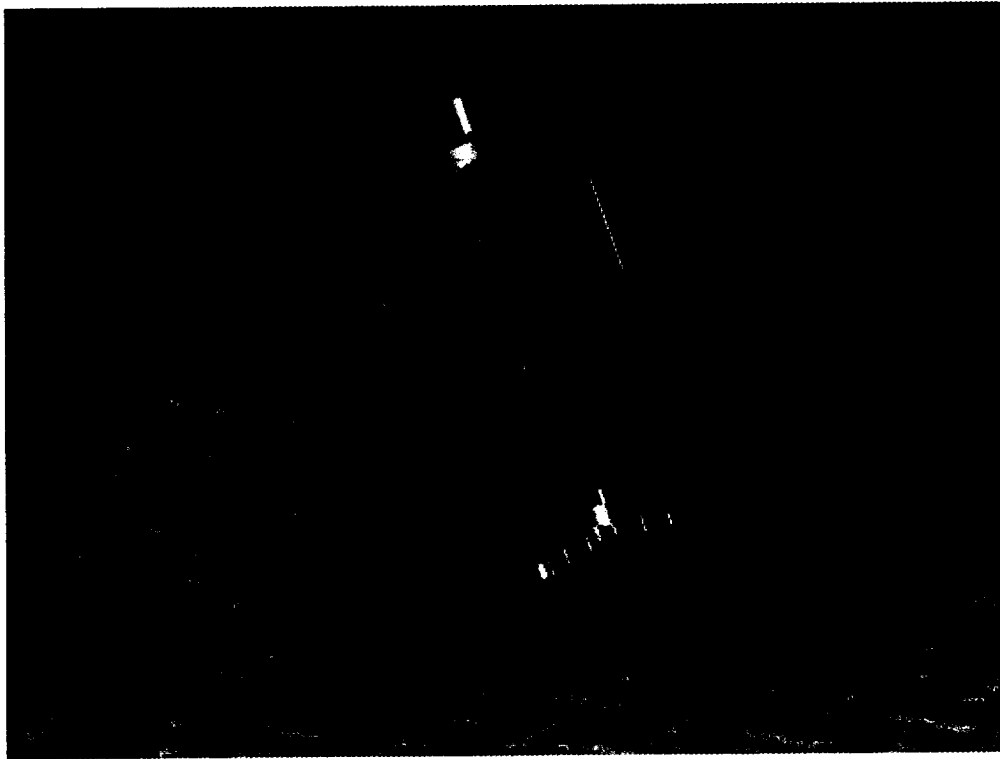
The motor mount base is constructed of 1x2 inch rectangular tubing that has been spot-welded together to prevent contortion with 6013-strength rod. The corners are 5/16 in steel with 1 ¼ in holes to hold the motor mount legs into place.



The crucial aspect of the base design was to minimize deflection of the upper system through a joist and beam structure as shown above. The Lincoln Arc Welding Book as a lightweight solution to supporting plate steel suggested this structure. The slot in the front of the structure is there to have a way for the chain to pass through without material to material contact

3.6 Guide Plate design

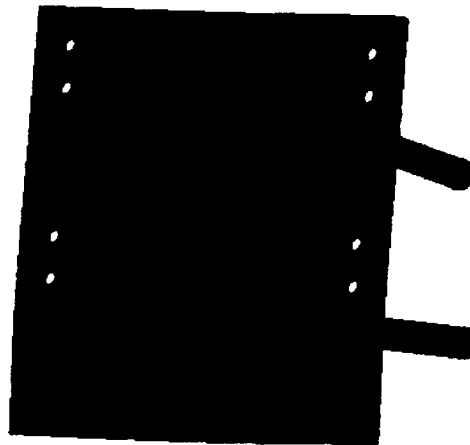
The Guide plate shown below is attached to the motor using $\frac{3}{8} \times 1 \frac{1}{2}$ inch bolts with nuts. The four bolts that extend out are $\frac{5}{8} \times 8$ inch threaded steel stock. When the threaded stock is in place on the motor mount a nut on both sides of the rear support of the motor mount proved the necessary mechanical advantage to tighten the chain attached to the motor. The bolts where designed to be no stronger than all of the eight bolts connecting the plate to the motor. This design is discuss in appendix 3.8



3.8 Motor Mount Guide plate Stress analysis

- The guide plate is used to transfer force on the motor to the motor mount
- The four bolts are threaded and are used to draw the motor away from the SRS in order to tighten the chain
- The stress analysis is evaluated at 800 lb of force per bolt with the motor mounting holes assumed fixed
- The stress analysis below shows a maximum stress of 30 MPa which is well under the allowable stress for steel.

Motor Guide Plate-Guide Plate :: Process-Bends Nodal Stress
Units : N/m²



Von Mises
7.316e+007
6.706e+007
6.097e+007
5.487e+007
4.878e+007
4.268e+007
3.659e+007
3.049e+007
2.439e+007
1.830e+007
1.220e+007
6.107e+006
1.139e+004

3.9 Material and Fastener parts list and strength calculations

The fasteners for the motor mount hold the system together and are an integral part of the system for strength. However as seen on the motor the manufactures hole diameters limit the size of the fastener to be used

Fastener List

- Four mounting rods with to nuts for mounting system to floor, 1.25 in dia. (See appendix 3.1)
- Eight bolts to mount motor to guide plate, with nuts, 5/16 in dia. x 1.5 in length
- Four bolts with nuts welded to guide plate for tension and mounting, 5/8 in dia x 8 in length
- Four bolts to secure bottom of motor to slides when required tension is met for the chain, 3/8/ in dia x 1in length

Material List

The rest of the motor mount is made up of 5/16 in thick mild plate steel.

Strength Calculations

The strength calculations for the fasteners were done using the following equations for Axial loads and Transverse loads yielding shear strength, tensile strength and Displacement of the fasteners (Consult Strength of materials book for variable specifications):

$$(1) \quad \sigma = P / A \quad (\text{Stress})$$

$$(2) \quad \tau = V / A \quad (\text{Shear Stress})$$

$$(3) \quad \delta = PL / AE \quad (\text{Displacement})$$

The Factor of safety of each component was figured using

$$n_s = \sigma_{all} / \sigma_{design}$$

4 Manufacturing of Motor Mount

The manufacturing of the motor mount was done using a vertical milling machine and an AC welder. A welding technique book was used for referencing welding technique and optimal weld design. Defection due to heat in the welding process was the major concern as well as quality control of the welds. The vertical mill was used to cut and size the steel plate components to size. The tolerances of the cuts were held to within 1/100 of an inch.

The procedure behind the manufacture is as follows. The motor mount base was constructed first. Then the motor mount upper was constructed second, followed by the guide plate. The motor mount base was constructed using a metal band saw and an AC welder. The 1 x 1.5 inch square tubing used in the base was cut to length using the bandsaw, and then welded together using 1/8 inch 6013 welding rod. All welds on the base were one pass welds. The motor mount upper was constructed, first by cutting the 5/16 inch steel pieces out of sheet metal with a cutting torch, then machining them to dimension with a vertical mill. Following the machining of each piece the mount was welded together using high amperage single and double pass welds to meet strength requirements. The last piece machined was the Guide plate. It was constructed from one piece of rectangular sheet metal that was machined to size, and then the bolt hole pattern was drilled accordingly. The 5/8 inch threaded bolts were then welded to the plate once it was secured to the motor in the motor mount.

5 Web Page Reference

An online parts library of the entire SRS assembly can be found, along with the actual animation and other information concerning this project at the following URL:

academic.oru.edu/~sch11607/proj1.html